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ABSTRACT

Literature on achievement effects of practical applications of group-based mastery learning in elementary and secondary schools over at least four weeks is examined, using the best-evidence synthesis review technique (a combination of meta-analysis and narrative reviews). There was essentially no evidence to support the effectiveness of group-based mastery learning on standardized achievement measures. Effects were generally positive, though moderate, on experimenter-made measures, with little evidence that they were maintained over time. These findings suggest the need for increased efforts to see how the compelling theories underlying mastery learning can achieve their potential. A 13-page list of references and three tables are presented. (SLD)

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Report No. 7

January, 1987

MASTERY LEARNING RECONSIDERED

Robert E. Slavin

The Johns Hopkins University

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The Center

The mission of the Center for Research on Elementary and Middle Schools is to produce useful knowledge about how elementary and middle schools can foster growth in students' learning and development, to develop and evaluate practical methods for improving the effectiveness of elementary and middle schools based on existing and new research findings, and to develop and evaluate specific strategies to help schools implement effective research-based school and classroom practices.

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This program focuses on improving the organizational performance of schools in adopting and adapting innovations and developing school capacity for change.

This report, prepared by the Elementary School Program, synthesizes research on the effects of mastery learning on student achievement.

Mastery Learning Reconsidered

Abstract

Several recent reviews and meta-analyses have claimed extraordinarily positive effects of mastery learning on student achievement, and Bloom (1984a, b) has hypothesized that mastery-based treatments will soon be able to produce "two-sigma" (i.e., two standard deviation) increases in achievement. This article examines the literature on achievement effects of practical applications of group-based mastery learning in elementary and secondary schools over periods of at least four weeks, using a review technique, "best-evidence synthesis," which combines features of meta-analytic and traditional narrative reviews. The review found essentially no evidence to support the effectiveness of group-based mastery learning on standardized achievement measures. On experimenter-made measures, effects were generally positive but moderate in magnitude, with little evidence that effects maintained over time. These results are discussed in light of the coverage vs. mastery dilemma posed by group-based mastery learning.

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Mastery Learning Reconsidered

The term "mastery learning" refers to a large and diverse category of instructional methods. The principal defining characteristic of mastery learning methods is the establishment of a criterion level of performance held to represent "mastery" of a given skill or concept, frequent assessment of student progress toward the mastery criterion, and provision of corrective instruction to enable students who do not initially meet the mastery criterion to do so on later parallel assessments (see Bloom, 1976; Block & Anderson, 1975). Bloom (1976) also includes an emphasis on appropriate use of such instructional variables as cues, participation, feedback, and reinforcement as elements of mastery learning, but these are not uniquely defining characteristics; rather, what defines mastery learning approaches is the organization of time and resources to ensure that most students are able to master instructional objectives.

There are three primary forms of mastery learning. One, called the Personalized System of Instruction (PSI) or the Keller Plan (Keller, 1968), is used primarily at the post-secondary level. In this form of mastery learning, unit objectives are established for a course of study and tests are developed for each. Students may take the test (or parallel forms of it) as many times as they wish until they achieve a passing score. To do this, students typically work on self-instructional materials and/or work with peers to learn the course content, and teachers may give lectures more to supplement than to guide the learning process (see Kulik, Kulik, and Cohen,

1979). A related form of mastery learning is continuous progress (e.g., Cohen, 1977), where students work on individualized units entirely at their own rate. Continuous progress mastery learning programs differ from other individualized models only in that they establish mastery criteria for unit tests and provide corrective activities to students who do not meet these criteria the first time.

The third form of mastery learning is called group-based mastery learning, or Learning for Mastery (LFM) (Block & Anderson, 1975). This is by far the most commonly used form of mastery learning in elementary and secondary schools. In group-based mastery learning the teacher instructs the entire class at one pace. At the end of each unit of instruction a "formative test" is given, covering the unit's content. A mastery criterion, usually in the range of 80-90% correct, is established for this test. Any students who do not achieve the mastery criterion on the formative test receive corrective instruction, which may take the form of tutoring by the teacher or by students who did achieve at the criterion level, small group sessions in which teachers go over skills or concepts students missed, alternative activities or materials for students to complete independently, and so on. In describing this form of mastery learning, Block and Anderson (1975) recommend that corrective activities be different from the kinds of activities used in initial instruction. Following the corrective instruction, students take a parallel formative or "summative" test. In some cases only one cycle of formative test-corrective instruction-parallel test is used, and the class moves on even if several students still have not achieved the mastery criterion; in others, the cycle may be repeated two or more times until virtually all students have gotten a passing score. All students who

achieve the mastery criterion at any point are generally given an "A" on the unit, regardless of how many tries it took for them to reach the criterion score.

The most recent full-scale review of research on mastery learning was published more than a decade ago, by Block and Burns (1976). However, in recent years two meta-analyses of research in this area have appeared, one by Kulik, Kulik, and Bangert-Drowns (1986) and one by Guskey and Gates (1985, 1986). Meta-analyses characterize the impact of a treatment on a set of related outcomes using a common metric called "effect size," the posttest score for the experimental group minus that for the control group divided by the control group's standard deviation (see Glass, McGaw, and Smith, 1981). For example, an effect size of 1.0 would indicate that on the average, an experimental group exceeded a control group by one standard deviation; the average member of the experimental group would score at the level of a student in the 84th percentile of the control group's distribution.

Both of the recent meta-analyses of research on mastery learning report extraordinary positive effects of this method on student achievement. Kulik et al. (1986) find mean effect sizes of 0.52 for pre-college studies and 0.54 for college studies. Guskey and Gates (1985) claim effect sizes of 0.94 at the elementary level (grades 1-8), 0.72 at the high school level, and 0.65 at the college level. Further, Walberg (1984) reports a mean effect size of 0.81 for "science mastery learning" and Lysakowski and Walberg (1982) estimate an effect size for "cues, participation, and corrective feedback," principal components of mastery learning, at 0.97. Bloom (1984, p. 7) claims an effect size of 1.00 "when mastery learning procedures are

done systematically and well," and has predicted that forms of mastery learning will be able to consistently produce achievement effects of "two sigma" (i.e., effect sizes of 2.00). To put these effect sizes in perspective, consider that the mean effect size for randomized studies of one-to-one adult tutoring reported by Glass, Cahen, Smith, and Filby (1982) was 0.62 (see Slavin, 1984). If the effects of mastery learning instruction approach or exceed those for one-to-one tutoring, then mastery learning is indeed a highly effective instructional method.

The purpose of the present article is to review the research on the effects of group-based mastery learning on the achievement of elementary and secondary students in an attempt to understand the validity and the practical implications of these findings. The review uses a method for synthesizing large literatures called "best-evidence synthesis" (Slavin, 1986), which combines the use of effect size as a common metric of treatment effect with narrative review procedures. Before synthesizing the "best evidence" on practical applications of mastery learning, the following sections discuss the theory on which group-based mastery learning is based, how that theory is interpreted in practice, and problems inherent to research on the achievement effects of mastery learning.

Mastery Learning in Theory and Practice

The theory on which mastery learning is based is quite compelling. Particularly in such hierarchically organized subjects as mathematics, reading, and foreign language, failure to learn prerequisite skills is likely to interfere with students' learning of later skills. For example, if a student fails to learn to subtract, he or she is sure to fail in learning long

division. If instruction is directed toward ensuring that nearly all students learn each skill in a hierarchical sequence, then students will have the prerequisite skills necessary to enable them to learn the later skills. Rather than accepting the idea that differences in student aptitudes will lead to corresponding differences in student achievement, mastery learning theory holds that instructional time and resources should be used to bring all students up to an acceptable level of achievement. Put another way, mastery learning theorists suggest that rather than holding instructional time constant and allowing achievement to vary (as in traditional instruction), achievement level should be held constant and time allowed to vary (see Bloom, 1968; Carroll, 1963).

In an extreme form, the central contentions of mastery learning theory are almost tautologically true. If we establish a reasonable set of learning objectives and demand that every student achieve them at a high level regardless of how long that takes, then it is virtually certain that all students will ultimately achieve that criterion. For example, imagine that students are learning to subtract two-digit numbers with renaming. A teacher might set a mastery criterion of 80% on a test of two-digit subtraction. After some period of instruction, the class is given a formative test, and let's say half of the class achieves at the 80% level. The teacher might then work with the "non-masters" group for one or more periods, and then give a parallel test. Say that half of the remaining students pass this time (25% of the class). If the teacher continues this cycle indefinitely, then all or almost all students will ultimately learn the skill, although it may take a long time for this to occur. Such a procedure would also accomplish two central goals of mastery learning, par-

ticularly as explicated by Bloom (1976): To reduce the variation in student achievement and to reduce or eliminate any correlation between aptitude and achievement. Since all students must achieve at a high level on the subtraction objective but students who achieve the criterion early cannot go on to new material, there is a ceiling effect built in to the procedure which will inherently cause variation among students to be small and correspondingly reduce the correlation between mathematics aptitude and subtraction performance. In fact, if we set the mastery criterion at 100% and repeated the formative test-corrective instruction cycle until all students achieved this criterion, then the variance on the subtraction test would be zero, as would the correlation between aptitude and achievement.

However, this begs several critical questions. If some students take much longer than others to learn a particular objective, then one of two things must happen. Either corrective instruction must be given outside of regular class time, or students who achieve mastery early on will have to waste considerable amounts of time waiting for their classmates to catch up. The first option, extra time, is expensive and difficult to arrange, as it requires that teachers be available outside of class time to work with the non-masters and that some students spend a great deal more time on any particular subject than they do ordinarily. The other option, putting rapid masters on hold with "enrichment" or "lateral extension" activities while corrective instruction is given, is unlikely to be beneficial for these students. For all students mastery learning poses a dilemma, a choice between content coverage and content mastery (see Arlin, 1984a; Mueller, 1976; Resnick, 1977). It may often be the case that even for low achievers, spending the time to master each objective may be less productive than covering more objectives (see, for example, Cooley & Leinhardt, 1980).

Problems Inherent to Mastery Learning Research

The nature of mastery learning theory and practice creates thorny problems for research on the achievement effects of mastery learning strategies. These problems fall into two principal categories: Unequal time and unequal objectives.

Unequal time. One of the fundamental propositions of mastery learning theory is that learning should be held constant and time should be allowed to vary, rather than the opposite situation held to exist in traditional instruction. However, if the total instructional time allocated to a particular subject is fixed, then a common level of learning for all students could only be achieved by taking time away from high achievers to increase it for low achievers, a leveling process that would in its extreme form be repugnant to most educators (see Arlin, 1982, 1984b; Arlin & Westbury, 1976; Fitzpatrick, 1985; Smith, 1981).

To avoid what Arlin (1984) calls a "Robin Hood" approach to time allocation in mastery learning, many applications of mastery learning provide corrective instruction during times other than regular class time, such as during lunch, recess, or after school (see Arlin, 1982). In short-term laboratory studies, the extra time given to students who need corrective instruction is often substantial. For example, Arlin & Webster (1983) conducted an experiment in which students studied a unit on sailing under mastery or non-mastery conditions for four days. After taking formative tests, mastery learning students who did not achieve a score of 80% received individual tutoring during times other than regular class time. Non-mastery students took the formative tests as final quizzes, and did not receive tutoring.

The mastery learning students achieved at twice the level of non-mastery students in terms of percent correct on daily chapter tests, an effect size of more than 3.0. However, mastery learning students spent more than twice as much time learning the same material. On a retention test taken four days after the last lesson, mastery students retained more than non-mastery students (effect size = .70). However, non-mastery students retained far more per hour of instruction than did mastery learning students (ES = -1.17).

In recent articles published in Educational Leadership and the Educational Researcher, Benjamin Bloom (1984a, b) noted that several dissertations done by his graduate students at the University of Chicago found effect sizes for mastery learning of one sigma or more (i.e., one standard deviation or more above the control group's mean). In all of these, corrective instruction was given outside of regular class time, increasing total instructional time beyond that allocated to the control groups. The additional time averaged 20-33% of the initial classroom instruction, or about one day per week. For example, in a two-week study in Malaysia by Nordin (1980) an extra period for corrective instruction was provided to the mastery learning classes, while control classes did other school work unrelated to the units involved in the study. A three-week study by Anania (1981) set aside one period each week for corrective instruction. In a study by Leyton (1983), students received 2-3 periods of corrective instruction for every 2-3 weeks of initial instruction. All of the University of Chicago dissertations cited by Bloom (1984 a, b) provided the mastery learning classes with similar amounts of additional instruction (Burke, 1983; Levin, 1979; Mevarech, 1980; Tenenbaum, 1982).

In discussing the practicality of mastery learning, Bloom (1984 a, p. 9) states that "... the time or other costs of the mastery learning procedures have usually been very small." It may be true that school districts could in theory provide tutors to administer corrective instruction outside of regular class time; the costs of doing so would hardly be "very small," but cost or cost-effectiveness is not at issue here. But as a question of experimental design, the extra time often given to mastery learning classes is a serious problem. It is virtually unheard-of in educational research outside of the mastery learning tradition to systematically provide an experimental group with more instructional time than a control group; presumably, any sensible instructional program would produce significantly greater achievement than a control method which involved 20-33% less instructional time.

It might be argued that mastery learning programs which provide corrective instruction outside of regular class time produce effects which are substantially greater per unit time than those associated with traditional instruction. However, computing "learning per unit time" is not a straightforward process. In the Arlin and Webster (1983) experiment discussed earlier, mastery learning students passed about twice as many items on immediate chapter tests as did control students, and the time allocated to the mastery learning students was twice that allocated to control. Thus, the "learning per unit time" was about equal in both groups. Yet on a retention test only four days later, the items passed per unit time were considerably higher for the control group. Which is the correct measure of learning per unit time, that associated with the chapter tests or that associated with the retention test?

Many mastery learning theorists (e.g., Block, 1972; Bloom, 1976; Guskey, 1985) have argued that the "extra time" issue is not as problematic as it seems, because the time needed for corrective instruction should diminish over time. The theory behind this is that by ensuring that all students have mastered the prerequisite skills for each new unit, the need for corrective instruction on each successive unit should be reduced. A few brief experiments using specially constructed, hierarchically organized curriculum materials have demonstrated that over as many as three successive units, time needed for corrective instruction does in fact diminish (Anderson, 1976; Arlin, 1973; Block, 1972). However, Arlin (1984) examined time-to-mastery records for students involved in a mastery learning program over a four-year period. In the first grade, the ratio of average time to mastery for the slowest 25% of students to that for the fastest 25% was 2.5 to 1. Rather than decreasing, as would have been predicted by mastery learning theorists, this ratio increased over the four year period. By the fourth grade, the ratio was 4.2 to 1. Thus, while it is theoretically possible that mastery learning procedures may ultimately reduce the need for corrective instruction, no evidence from long-term practical applications of mastery learning supports this possibility at present.

It should be noted that many studies of mastery learning do hold total instruction time more or less constant across experimental and control conditions. In discussing the "best evidence" on practical applications of mastery learning, issues of time for corrective instruction will be explored further.

Unequal objectives. An even thornier problem posed by research on mastery learning revolves around the question of achievement measures used as dependent variables. Most studies of mastery learning use experimenter-made summative achievement tests as the criterion of learning effects. The danger inherent in the use of such tests is that they will correspond more closely to the curriculum taught in the mastery learning classes than to that taught in control classes. Some articles describing mastery learning experiments (e.g., Kersh, 1970; Lueckemeyer & Chiappetta, 1981) describe considerable efforts to ensure that experimental and control classes were pursuing the same objectives, and many studies administer the formative tests used in the mastery learning classes as quizzes in the control classes, which in theory should help focus the control classes on the same objectives. On the other hand, many other studies specified that students used the same texts and other materials but did not use formative tests in the control group or otherwise focus the control groups on the same objectives as those pursued in the mastery learning classes (e.g., Cabezon, 1984; Crotty, 1975).

The possibility that experimenter-made tests will be biased toward the objectives taught in experimental groups exists in all educational research which uses such tests, but it is particularly problematic in research on mastery learning, which by its nature focuses teachers and students on a narrow and explicitly defined set of objectives. When careful control of instruction methods, materials, and tests is not exercised, there is always a possibility that the control group is learning valuable information or skills not learned in the mastery learning group but not assessed on the experimenter-made measure.

Even when instructional objectives are carefully matched in experimental and control classes, use of experimenter-made tests keyed to what is taught in both classes can introduce a bias in favor of the mastery learning treatment. As noted earlier, when time for corrective instruction is provided within regular class time (rather than after class or after school), mastery learning trades coverage for mastery. The overall effects of this trade must be assessed using broadly based measures. What traditional whole-class instruction is best at, at least in theory, is covering material. Mastery learning proponents point out that material covered is not necessarily material learned. This is certainly true, but it is just as certainly true that material not covered is material not learned. Holding mastery learning and control groups to the same objectives in effect finesses the issue of instructional pace by only measuring the objectives that are covered by the mastery learning classes. If the control classes in fact cover more objectives, or could have done so had they not been held to the same pace as the mastery learning classes, this would not be registered on the experimenter-made test.

Two studies clearly illustrate the problems inherent in the use of experimenter-made tests to evaluate mastery learning. One is a year-long study of mastery learning in grades 1-6 by Anderson, Scott, and Hutlock (1976), which is described in detail later in this review. On experimenter-made math tests the mastery learning classes significantly exceeded control at every grade level (mean effect size = +.64). On a retention test administered three months later the experimental-control differences were still substantial (ES = +.49). However, the experimenters also used the mathematics scales from the standardized California Achievement Test as a dependent

variable. On this test the experimental-control differences were effectively zero (ES = +.04).

A study by Taylor (1973) in ninth grade algebra classes -- although not strictly speaking a study of mastery learning -- nevertheless illustrates the dilemma involved in the use of experimenter-made tests in evaluation of mastery learning programs. At the beginning of the semester, students in the experimental classes were each given a copy of a "minimal essential skills" test, and were told that to pass the course they would need to obtain a score of at least 80% on a parallel form of the test. About three weeks before the end of the semester, another parallel form of the final test was administered to students, and the final three weeks was spent on remedial work and retesting for students who needed it (while other students worked on enrichment activities). At the end of the semester the final test was given. A similar procedure was followed for the second semester.

Experimenter-made as well as standardized measures were used to assess the achievement effects of the program. On the minimum essential skills section of the experimenter-made test, scores averaged 87.3% correct, dramatically higher than they had been on the same test in the same schools the previous year (55.4%). On a section of the experimenter-made test covering skills "beyond, but closely related to, minimum essentials," differences favoring the experimental classes were still substantial, 44.6% correct vs. 29.2%. Differences on the minimum essentials subtest of the standardized Cooperative Algebra Test also favored the experimental group (ES = +.47). However, on the section of the standardized test covering skills <u>beyond</u> minimum essentials, the control group exceeded the experimental group (ES = -.25).

The Taylor (1973) intervention does not qualify as mastery learning because it involved only one feedback-corrective instruction cycle per semester. However, the study demonstrates a problem characteristic of mastery learning studies which use experimenter-made tests as dependent measures. Had Taylor only used the experimenter-made test, his study would have appeared to provide overwhelming support for the experimental procedures. However, the results for the standardized tests indicated that students in the control group (the previous year) were learning materials that did not appear on the experimenter-made tests. The attention and efforts of teachers as well as students were focused on a narrow set of instructional objectives which constituted only about 30% of the items on the broader-based standardized measure.

These observations concerning problems in the use of experimenter-made measures do not imply that all studies which use them should be ignored. Rather, they are meant to suggest extreme caution and careful reading of details of each such study before conclusions are drawn.

Methods

This review uses a method called "best-evidence synthesis," procedures described by Slavin (1986) for synthesizing large literatures in social science. This section, "Methods," outlines the specific procedures used in preparing the review, including such issues as how studies were located, which were selected for inclusion, how effect sizes were computed, how studies were categorized, and how the question of pooling of effect sizes was handled.

Literature Search Procedures

The first step in conducting the best-evidence synthesis was to locate as complete as possible a set of studies of mastery learning. Several sources of references were used. The ERIC system and Dissertation Abstracts produced hundreds of citations in response to the keywords "mastery learning." Additional sources of citations included a bibliography of mastery learning studies compiled by Hymel (1982), earlier reviews and meta-analyses on mastery learning, and references in the primary studies. Papers presented at the American Educational Research Association meetings since 1976 were solicited from their authors. Dissertations were ordered from University Microfilms and from the University of Chicago, which does not cooperate with University Microfilms.

Criteria for Study Inclusion

The studies on which this review is primarily based had to meet a set of *a priori* criteria with respect to germaneness and methodological adequacy.

Germaneness. To be considered germane to the review, all studies had to evaluate group-based mastery learning programs in regular (i.e., non-special) elementary and secondary classrooms. "Group-based mastery learning" was defined as any instructional method which had the following characteristics:

1. Students were tested on their mastery of instructional objectives at least once each month. A mastery criterion was set (e.g., 80% correct) and students who did not achieve this criterion on an initial formative test received corrective instruction and a second formative or summative test. This cycle could be repeated one or more times. Studies were included regardless of the form of corrective instruction used and regardless of whether corrective instruction was given during or outside of regular class time.

2. Before each formative test, students were taught as a total group. This requirement excluded studies of individualized or continuous progress forms of mastery learning and studies of the Personalized System of Instruction. However, studies in which mastery learning students worked on individualized materials as corrective (not initial) instruction were included.

3. Mastery learning was the only or principal intervention. This excluded comparisons such as those in two studies by Mevarech (1985a, b) evaluating a combination of mastery learning and cooperative learning, and comparisons involving enhancement of cognitive entry behaviors (e.g., Leyton, 1983).

Studies evaluating programs similar to mastery learning but conducted before Bloom (1968) described it were excluded (e.g., Rankin, Anderson, & Bergman, 1936). Other than this, no restrictions were placed on sources or types of publications. Every attempt was made to locate dissertations, ERIC documents, and conference papers as well as published materials.

Methodological Adequacy. Criteria for methodological adequacy were as follows.

1. Studies had to compare group-based mastery learning programs to traditional group-paced instruction not using the feedback-corrective cycle. A small number of studies (e.g., Katims & Jones, 1985; Levine & Stark, 1982; Strassler & Rochester, 1982) which compared achievement under mastery learning to that during previous years (before mastery learning was introduced) were excluded, on the basis that changes in grade-to-grade promotion policies, curriculum alignment, and other trends in recent years make year-to-year changes difficult to ascribe to any one factor.

2. Evidence had to be given that experimental and control groups were initially equivalent, or the degree of non-equivalence had to be quantified and capable of being adjusted for in computing effect sizes. This excluded a small number of studies which failed to either give pretests or to randomly assign students to treatments (e.g., Dillashaw & Okey, 1983).

3. Study duration had to be at least four weeks (20 hours). This restriction excluded a large number of brief, often quite artificial experiments. The reason for it was to concentrate the review on mastery learning procedures that could in principle be used over extended time periods;

procedures which teachers might be able to sustain for a week or two but not longer were thus excluded. One four-week study by Strasler (1979) was excluded on the basis that it was really two two-week studies on two completely unrelated topics, ecology and geometry. The four-week requirement caused by far the largest amount of exclusion of studies included in previous reviews and meta-analyses. For example, of 25 elementary and secondary achievement studies cited by Guskey and Gates (1985), eleven (with a median duration of one week) were excluded by this requirement.

4. At least two experimental and two control classes and/or teachers had to be involved in the study. This excluded a few studies (e.g., Collins, 1971; Leyton, 1983; Long, Okey, & Yeany, 1981; Mevarech, 1985a; Tenenbaum, 1982) in which treatment effects were completely confounded with teacher/class effects. Also excluded were a few studies in which several teachers were involved but each taught a different subject (Guskey, 1982, 1984; Rubovits, 1975). Because it would be inappropriate to compute effect sizes across the different subjects, these studies were seen as a set of two-class comparisons, each of which confounded teacher and class effects with treatment effects.

5. The achievement measure used had to be an assessment of objectives taught in control as well as experimental classes. This requirement was liberally interpreted, and excluded only one study, a dissertation by Froemel (1980) in which the mastery learning classes' summative tests were used as the criterion of treatment effects and no apparent attempt was made to see that the control classes were pursuing the same objectives. In cases in which it was unclear to what degree control classes were held to the same

objectives as experimental classes and experimenter-made measures were used, the studies were included. These studies are identified and discussed later in this review, and their results should be interpreted with a great deal of caution.

Also excluded were studies which used grades as the only dependent measures (e.g., Mathews, 1982; Wortham, 1980). In group-based mastery learning, grades are increased as part of the treatment, as students have opportunities to take tests over to try to improve their scores. They are thus not appropriate as measures of the achievement effects of the program. Similarly, studies which used time on-task as the only dependent measure were excluded (e.g., Fitzpatrick, 1985).

Computation of Effect Sizes

The size and direction of effects of mastery learning on student achievement are presented throughout this review in terms of effect size. Effect size, as described by Glass et al. (1981), is the difference between experimental and control posttest means divided by the control group's posttest standard deviation. However, this formula was adapted in the present review to take into account pretest or ability differences between the experimental and control groups. If pretests were available, then the formula used was the difference in experimental and control gains divided by the control group's posttest standard deviation. If ability measures rather than pretests were presented, then the experimental-control difference on these measures (divided by the control group's standard deviation) was subtracted from the posttest effect size. The reason for these adjustments is that in studies of achievement posttest scores are so dependent on pretest levels

that any pretest differences are likely to be reflected in posttests, correspondingly inflating or deflating effect sizes computed on posttests alone.

Because individual-level standard deviations are usually of concern in mastery learning research, most studies which met other criteria for inclusion presented data sufficient for direct computation of effect size. In many studies, data analyses used class means and standard deviations, but individual-level standard deviations were also presented. In every case the individual-level standard deviations were used to compute effect sizes; class-level standard deviations are usually much smaller than individual-level SD's, inflating effect size estimates. Also, note that the control group standard deviation, not a pooled standard deviation, was always used, as mastery learning often has the effect of reducing achievement standard deviations.

In the few cases in which data necessary for computing effect sizes were lacking in studies which otherwise met criteria for inclusion, the studies' results were indicated in terms of their direction and statistical significance.

tery learning and control classes are held to precisely the same objectives but the control classes are not allowed to move ahead if they finish those objectives before their mastery learning counterparts do, then the traditional model is deprived of its natural advantage, the capacity to cover material rapidly. A "fair" measure of student achievement in a mastery learning experiment would have to register both coverage and mastery, so that if the control group covered more objectives than the mastery learning group its learning of these additional objectives would be registered. The "strong claim" would hold that even allowing control classes to proceed at their own rate and even using such a "fair" achievement measure, mastery learning would produce more achievement than control methods.

The best evidence for the "strong claim" would probably come from studies in which mastery learning and control classes studied precisely the same objectives using the same materials and lessons and the same amount of allocated time, but in which teachers could determine their own pace of instruction and achievement measures covered the objectives reached by the fastest-moving class. Unfortunately, such studies are not known to exist. However, a good approximation of these experimental design features is achieved by studies which hold allocated time constant and use standardized tests as the criterion of achievement. Assuming that curriculum materials are not specifically keyed to the standardized tests in either treatment, these tests offer a means of registering both mastery and coverage. In such basic skills areas as mathematics and reading, the standardized tests are likely to have a high overlap with the objectives pursued by mastery learning teachers as well as by control teachers.

Research on Achievement Effects of Group-Based Mastery Learning

What are the effects of group-based mastery learning on the achievement of elementary and secondary students? In essence, there are three claims that proponents of mastery learning might make for the effectiveness of mastery learning. These are as follows:

1. Mastery learning is more effective than traditional instruction even when instructional time is held constant and fair achievement measures are used.

This might be called the "strong claim" for the achievement effects of mastery learning. It is clear, at least in theory, that if mastery learning procedures greatly increase allocated time for instruction by providing enough additional time for corrective instruction to bring all students to a high level of mastery, then mastery learning students will achieve more than traditionally taught control students. But it is less obviously true that the additional time for corrective instruction is more productive in terms of student achievement than it would be to simply increase allocated time for the control students. The "strong claim" asserts that time used for corrective instruction (along with the other elements of mastery learning) is indeed more productive than time used for additional instruction to the class as a whole.

Similarly, it is clear (in theory) that if students who experienced mastery learning are tested on the specific objectives they studied, they will score higher on those objectives than will students who were studying similar but not identical objectives. Further, it is likely that even if mas-

2. Mastery learning is an effective means of ensuring that teachers adhere to a particular curriculum and students learn a specific set of objectives (the "curricular focus" claim).

A "weak claim" for the effectiveness of mastery learning would be that these methods focus teachers on a particular set of objectives which is held to be superior to those which might have been pursued by teachers on their own. This might be called the "curricular focus" claim. For example, consider a survey course on U.S. history. Left to their own devices, some teachers might teach details about individual battles of the Civil War; others might entirely ignore the battles and focus on the economic and political issues; and still others might approach the topic in some third way, combine both approaches, or even teach with no particular plan of action. A panel of curriculum experts might determine that there is a small set of critical understandings about the Civil War that all students should have, and they might devise a criterion-referenced test to assess these understandings. If it can be assumed that the experts' judgments are indeed superior to those of individual teachers, then teaching to this test may not be inappropriate, and mastery learning may be a means of holding students and teachers to the essentials, relegating other concepts they might have learned (which are not on the criterion-referenced test) to a marginal status. It is no accident that mastery learning grew out of the behavioral objectives/criterion-referenced testing movement (see Bloom, Hastings, & Madaus, 1971); one of the central precepts of mastery learning is that once critical objectives are identified for a given course, then students should be required to master those and only those objectives. Further, it is interesting to note that in recent years the mastery learning movement has

often allied itself with the "curriculum alignment" movement, which seeks to focus teachers on objectives that happen to be contained in district- and/or state-level criterion-referenced minimum competency tests as well as norm-referenced standardized tests (see Levine, 1985).

The "curricular focus" claim, that mastery learning may help focus teachers and students on certain objectives, is characterized here as a "weak claim" because it requires a belief that the objectives pursued by the mastery learning program represent the totality of the subject at hand, and that all other (unmeasured) objectives are essentially worthless. Critics (e.g., Resnick, 1977) point out with some justification that a focus on a well-defined set of minimum objectives may place a restriction on the maximum that students might have achieved. However, in certain circumstances it may well be justifiable to hold certain objectives to be essential to a course of study, and mastery learning may represent an effective means of ensuring that nearly all students have attained these objectives.

The best evidence for the "curricular focus" claim would come from studies in which curriculum experts formulated a common set of objectives to be pursued equally by mastery learning and control teachers within an equal amount of allocated time. If achievement on the criterion-referenced assessments were higher in mastery learning than in control classes then we could at least make the argument that the mastery learning students have learned more of the essential objectives, even though the control group may have learned additional, presumably less essential concepts.

3. Mastery learning is an effective use of additional time and instructional resources to bring almost all students to an acceptable level of achievement (the "extra time" claim).

A second "weak claim" would be that given the availability of additional teacher and student time for corrective instruction, mastery learning is an effective means of ensuring all students a minimal level of achievement. As noted earlier, in an extreme form this "extra time" claim is almost axiomatically true. Leaving aside cases of serious learning disabilities, it should certainly be possible to ensure that virtually all students can achieve a minimal set of objectives in a new course if an indefinite amount of one-to-one tutoring is available to students who initially fail to pass formative tests. However, it may be that even within the context of the practicable, providing students with additional instruction if they need it will bring almost all to a reasonable level of achievement.

The reason that this is characterized here as a "weak claim" is that it begs the question of whether the additional time used for corrective instruction is the best use of additional time. What could the control classes do if they also had more instructional time? However, the "extra time" issue is not a trivial one, as it is not impossible to routinely provide corrective instruction to students who need it outside of regular class time. For example, this might be an effective use of Chapter I or special education resource pull-outs, a possibility that is discussed later.

The best evidence for this claim would come from studies which provided mastery learning classes with additional time for corrective instruction and used achievement tests that covered all topics which could have been studied

by the fastest-paced classes (e.g., standardized tests). However, such studies are not known to exist; the best existing evidence for the "extra time" claim is from studies which used experimenter-made achievement measures and provided corrective instruction outside of class time.

Evidence for the "Strong Claim"

Table 1 summarizes the major characteristics and findings of seven mastery learning studies which met the inclusion criteria discussed earlier, provided equal time for experimental and control classes, and used standardized measures of achievement.

Table 1 Here

Table 1 clearly indicates that the effects of mastery learning on standardized achievement measures are extremely small, at best. The median effect size across all seven studies is essentially zero (ES = + .04). The only study with a non-trivial effect size (ES=+.25), a semester-long experiment in inner-city Chicago elementary schools by Katims, Smith, Steele, & Wick (1977), also had a serious design flaw. Teachers were allowed to select themselves into mastery learning or control treatments or were assigned to conditions by their principals. It is entirely possible that the teachers who were most interested in using the new methods and materials, or those who were named by their principals to use the new program, were better teachers than were the control teachers. In any case, the dif-

ferences were not statistically significant when analyzed at the class level, were only marginally significant (p=.071) for individual-level gains, and amounted to an experimental-control difference of only 11% of a grade equivalent.

The Katims et al. (1977) study used a specially developed set of materials and procedures which became known as the Chicago Mastery Learning Reading program, or CMLR. This program provides teachers with specific instructional guides, worksheets, formative tests, corrective activities, and extension materials. A second study of CMLR by Jones, Monsaas, & Katims (1979) compared matched CMLR and control schools over a full year. This study found a difference between CMLR and control students on the Iowa Test of Basic Skills Reading Comprehension scale that was marginally significant at the individual level but quite small (ES=+.09). In contrast, on experimenter-made "end of cycle" tests the mastery learning classes did significantly exceed control (ES=+.18). A third study of CMLR by Katims and Jones (1985) did not qualify for inclusion in Table 1 because it compared year-to-year gains in grade equivalents rather than comparing experimental to control groups. However, it is interesting to note that the difference in achievement gains between the cohort of students who used the CMLR program and those in the previous year who did not was only 0.16 grade equivalents, which is similar to the results found in the Katims et al. (1977) and Jones et al. (1979) experimental-control comparisons.

One of the most important studies of mastery learning is the year-long Anderson, Scott, and Hutlock (1976) experiment briefly described earlier. This study compared students in grades 1-6 in one mastery learning and one

control school in Lorain, Ohio. The school populations were similar, but there were significant pretest differences at the first and fourth grade levels favoring the control group. To ensure initial equality in this non-randomized design, students were individually matched on the Metropolitan Readiness Test (grades 1-3) or the Otis-Lennon Intelligence Test (grades 4-6). In the mastery learning school, students experienced the form of mastery learning described by Block and Anderson (1975). The teacher presented a lesson to the class and then assessed student progress on specific objectives. "Errors ... were remediated through the use of both large-group and small-group re-learning and review sessions. After every student had demonstrated mastery on the formative test for each unit, the class moved on to the next unit" (Anderson et al., 1976, p. 4).

One particularly important aspect of the Anderson et al. (1976) study is that it used both standardized tests and experimenter-made, criterion-referenced tests. The standardized tests were the Computations, Concepts, and Problem Solving scales of the California Achievement Test. The experimenter-made test was constructed by the project director (Nicholas Hutlock) to match the objectives taught in the mastery learning classes. Control teachers were asked to examine the list of objectives and identify any they did not teach, and these were eliminated from the test.

The results of the study were completely different for the two types of achievement tests. On the experimenter-made tests, students in the mastery learning classes achieved significantly more than did their matched counterparts at every grade level (mean ES=+.64). A retention test based on the same objectives was given three months after the end of the intervention

period, and mastery learning classes still significantly exceeded control (ES=+.49). However, on the standardized tests, these differences were not registered. Mastery learning students scored somewhat higher than control on Computations (ES=+.17) and Problem Solving (ES=+.07), but the control group scored higher on Concepts (ES=-.12).

The Anderson et al. (1976) finding of marked differences in effects on standardized and experimenter-made measures counsels great caution in interpreting results of other studies which used experimenter-made measures only. In a year-long study of mathematics, it is highly unlikely that a standardized mathematics test would fail to register any meaningful treatment effect. Therefore, it must be assumed that the strong positive effects found by Anderson et al. (1976) on the experimenter-made tests are mostly or entirely due to the fact that these tests were keyed to the mastery learning classes' objectives. It may be that the control classes covered more objectives than the mastery learning classes, and that learning of these additional objectives was registered on the standardized but not the experimenter-made measures.

Another important study of mastery learning at the elementary level is a dissertation by Kersh (1971), in which eleven fifth-grade classes were randomly assigned to mastery learning or control conditions for an entire school year. Two schools were involved, one middle-class and one lower-class. Students' math achievement was assessed about once each month in the mastery learning classes, and peer tutoring, games, and other alternative activities were provided to students who did not show evidence of mastery. Control classes were untreated. The study results did not favor either

treatment overall on the Stanford Achievement Test's Concepts and Applications scales. Individual-level effect sizes could not be computed, as only class-level means and standard deviations were reported. However, class-level effect sizes were essentially zero in any case (ES=-.06). On an experimenter-made criterion-referenced test not specifically keyed to the mastery objectives the results were no more conclusive; class-level effects slightly favored the control group (ES=-.20). Effects somewhat favored mastery learning in the lower-class school and favored the control group in the middle-class school, but since none of the differences approached statistical significance these trends may just reflect teacher effects on random variation.

In a recent study by Gutkin (1985), 41 first-grade classes in New York City were randomly assigned to mastery learning or control treatments. The article does not describe the mastery learning treatment in detail, except to note that monthly formative tests were given to assess student progress through prescribed instructional units. The mastery learning training also included information on classroom management skills, process-product research, and performance-based teacher education, and teachers received extensive coaching, routine feedback from teacher trainers, and scoring services for formative and summative tests. After one year, mastery learning-control-differences did not approach statistical significance in Total Reading on the California Achievement Test (ES=+.12). However, effects were more positive on a Phonics subscale (ES=+.36) than on Reading Vocabulary (ES=+.04) or Reading Comprehension (ES=+.15). Phonics, with its easily measurable objectives, may lend itself better to the mastery learning approach than do reading comprehension or vocabulary.

Studies using standardized measures at the secondary level are no more supportive of the "strong claim" than are the elementary studies. A 26-week experiment in inner-city, mostly black, Philadelphia junior and senior high schools assessed mastery learning in ninth grade "consumer mathematics," a course provided for students who do not qualify for Algebra I (Slavin & Karweit, 1984). Twenty-five teachers were randomly assigned to mastery learning or control treatments, both of which used the same books, worksheets, and quizzes in the same cycle of activities. However, instructional pace was not held constant. After each one-week unit (approximately), mastery learning classes took a formative test, and then any students who did not achieve a score of at least 80% received corrective instruction from the teacher while those who did achieve at that level did enrichment activities. The formative tests were used as quizzes in the control group, and after taking the quizzes the class went on to the next unit.

Results on a shortened version of the Comprehensive Test of Basic Skills Computations and Concepts and Applications scales indicated no differences between mastery learning and control treatments (ES=+.02), and no interaction with pretest level; neither low nor high achievers benefited from the mastery learning model. It is interesting to note that there were two other treatment conditions evaluated in this study, a cooperative learning method called Student Teams-Achievement Divisions or STAD (Slavin, 1983) and a combination of STAD and mastery learning. STAD classes did achieve significantly more than control (ES=+.19), but adding the mastery learning component to STAD had little additional achievement effect (ES=+.03).

A five-week study by Chance (1980) compared randomly assigned mastery learning and control methods in teaching reading to students in an all-black, inner-city New Orleans school. Approximately once each week, students in the mastery learning groups took formative tests on unit objectives. If they did not achieve at 80% (on three quizzes) or 90% (on one), they received tutoring, games, and/or manipulatives to correct their errors and had three opportunities to pass. No effects for students at any level of prior performance were found on the Gates-McGinitie Comprehension Test. However, it may be unrealistic to expect effects on a standardized measure after only five weeks.

Overall, research on the effects of mastery learning on standardized achievement test scores provides little support for the "strong claim" that holding time and objectives constant, mastery learning will accelerate student achievement. The studies assessing these effects are not perfect; particularly when mastery learning is applied on a fairly wide scale in depressed inner-city schools, there is reason to question the degree to which the model was faithfully implemented. However, most of the studies used random assignment of classes or students to treatments, study durations approaching a full school year, and measures which registered coverage as well as mastery. Not one of the seven studies found effects of mastery learning which even reached conventional levels of statistical significance (even in individual-level analyses), much less educational significance. If group-based mastery learning had strong effects on achievement in such basic skills as reading and math, these studies would surely have detected them.

Evidence for the "Curricular Focus" Claim

Table 2 summarizes the principal evidence for the "curricular focus" claim, that mastery learning is an effective means of increasing student achievement of specific skills or concepts held to be the critical objectives of a course of study. The studies listed in the table are those which (in addition to meeting general inclusion criteria) used experimenter-made, criterion-referenced measures and apparently provided experimental and control classes with equal amounts of instructional time. It is important to note that the distinction between the equal-time studies listed in Table 2 and the unequal-time studies in Table 3 is often subtle and difficult to discriminate, as many authors did not clarify when or how corrective instruction was delivered or what the control groups were doing during the time when mastery learning classes received corrective instruction.

Table 2 Here

A total of eight studies met the requirements for inclusion in Table 2. Three of these (Anderson et al, 1976; Jones et al., 1979; Kersh, 1970) were studies which used both standardized and experimenter-made measures, and were therefore also included in Table 1 and discussed earlier.

All but one (Kersh, 1970) of the studies listed in Table 2 found positive effects of mastery learning on achievement of specified objectives, with five studies falling in an effect size range from +.18 to +.27. The overall

median effect size for the seven studies which used immediate posttests is +.24. However, the studies vary widely in duration, experimental and control treatments, and other features, so this median value should be cautiously interpreted.

Fuchs, Tindal, & Fuchs (1985) conducted a small and somewhat unusual study of mastery learning in rural first-grade reading classes. Students in four classes were randomly assigned to one of two treatments. In the mastery learning classes, students were tested on oral reading passages in their reading groups each week. The whole reading group reviewed each passage until at least 80% of the students could read the passage correctly at 50 words per minute. The control treatment was held to be the form of "mastery learning" recommended by basal publishers. These students were given unit tests every 4-6 weeks, but all students went on to the next unit regardless of score. Surprisingly, the measure on which mastery learning classes exceeded control was "end-of-book" tests provided with the basals (ES=+.35), not passage reading scores which should have been more closely related to the mastery learning procedures (ES=+.05). On both measures it was found that while low achievers benefited from the mastery learning approach, high achievers generally achieved more in the control classes. Since the control teachers were presumably directing their efforts toward the objectives assessed in the end-of-book tests to the same degree as the mastery learning teachers, the results on this measure are probably fair measures of achievement. However, the Fuchs et al. (1985) study may be more a study of the effects of repeated reading than of mastery learning per se. Research on repeated reading (e.g., Dahl, 1979) has found this practice to increase comprehension of text.

Another small and unusual study at the elementary level was reported by Wyckoff (1974), who randomly assigned four sixth grade classes to experimental or control conditions for a nine-week anthropology unit. Following teaching of each major objective, students were quizzed. If the class median was at least 70% correct, the class moved on to the next objective; otherwise, those who scored less than 70% received peer tutoring or were given additional reading or exercises. The control groups used precisely the same materials, tests, and schedule. The achievement results were not statistically significant, but they favored the mastery learning classes (ES=+.24). However, this trend was entirely due to effects on low performing readers (ES=+.58), not high-ability readers (ES=+.03).

One remarkable study spanning grades 3, 6, and 8 was reported in a dissertation by Cabezon (1984). The author, the director of the National Center for Curriculum Development in Chile, was charged with implementation of mastery learning throughout that country. Forty-one elementary schools throughout Chile were selected to serve as pilots, and an additional 2,143 schools began using mastery learning two years later. Three years after the pilots had begun, Cabezon randomly selected a sample of schools that had been using mastery learning for three years, for one year, or not at all. Within each selected school two classes at the third, sixth, and eighth grade level were selected.

The form of mastery learning used was not clearly specified, but teachers were expected to assess student progress every 2-3 weeks and to provide corrective instruction to those who needed it. Two subjects were involved, Spanish and mathematics.

Unfortunately, the classes that had used mastery learning for three years were found to be much higher in socioeconomic status and mean IQ level than were control classes. Because of this problem these comparisons did not meet the inclusion criteria. However, the classes that had used mastery learning for one year were comparable to the control classes in SES and only slightly higher in IQ.

The study results, summarized in Table 2, indicated stronger effects of mastery learning in Spanish than in math, and stronger effects in the early grades than in later ones, with an overall mean of +0.27. However, while all teachers used the same books, it is unclear to what degree control teachers were held to or even aware of the objectives being pursued by the mastery learning schools.

Two studies at the secondary level assessed both immediate and long-term impacts of mastery learning. One was a study by Lueckemeyer and Chiappetta (1981), who randomly assigned tenth graders to six mastery learning or six control classes for a six-week human physiology unit. In the mastery learning classes, students were given a formative test every two weeks. They were then given two days to complete corrective activities for any objectives on which they did not achieve an 80% score, following which they took a second form of the test, which was used for grading purposes. Students who achieve the 80% criterion on the first test were given material to read or games to play while their classmates received corrective instruction. The control group studied the same material and took the same tests, but did not receive the two-day corrective sessions. The control teachers were asked to complete the three two-week units in six weeks, but were not held

to the same schedule as the mastery classes. In order to have time to fit in the two days for corrective instruction every two weeks, the mastery learning classes "had to condense instruction... and to guard carefully against any wasted time (C.L. Lueckemeyer, personal communication, November 4, 1986).

On an immediate posttest the mastery learning classes achieved significantly more than the control group (ES=+.39), but on a retention test given four weeks later the difference had disappeared. The study's authors reported the statistically significant effects on posttest achievement but noted that "it is questionnable whether such a limited effect on achievement is worth the considerable time required for the development and management of such an instructional program" (Lueckemeyer & Chiappetta, 1981, p. 273). Further, it is unclear whether the control groups required the full six weeks to cover the material. Any additional information students in the control group learned (or could have learned) would of course not have been registered on the experimenter-made test.

In a 15-week experiment in ninth grade chemistry and physics classes by Dunkelberger and Heikkinen (1984), students were randomly assigned to mastery learning or control classes. In the mastery learning classes students had several chances to meet an 80% criterion on parallel formative tests. Control students took the tests once and received feedback on their areas of strength and weakness. All students, control as well as experimental, had the same corrective activities available during a regularly scheduled free time. However, mastery learning students took much greater advantage of these activities. The total time used by the experimental group was thus

greater than that used by control students, but since the total time available was held constant, this was categorized as an equal-time study.

For reasons that were not stated, the implementation of the 15-week chemistry and physics unit was concluded in January, but the posttests were not given until June, 4 months later. For this reason the program's effects are listed as retention measures only. Effects favored the mastery learning classes (ES=+.26).

Overall, the effects summarized in Table 2 could be interpreted as supporting the "curricular focus" claim. The effects of mastery learning on experimenter-made, criterion-referenced measures are moderate but consistently positive. The only study with an effect size above a modest 0.27 was the Anderson et al. (1976) study, in which the experimenter-made measures were specifically keyed to the material studied only by the mastery learning classes. Two studies found that the effects of mastery learning were greatest for low achievers, as would be expected from mastery learning theory.

However, the meaning of the results summarized in Table 2 is far from clear. The near-zero effects of mastery learning on standardized measures (Table 1) and in particular the dramatically different results for standardized and experimenter-made measures reported by Anderson et al. (1976) suggest that the effects of mastery learning on experimenter-made measures result from a shifting of instructional focus to a particular set of objectives neither more nor less valuable than those pursued by the control group. Unfortunately, it is impossible to determine from reports of mastery learning studies the degree to which control teachers were focusing on the objectives assessed on the experimenter-made measures, yet understanding this is crucial to understanding the effects reported in these studies.

Evidence for the Extra-Time Claim

The problem of unequal time for experimental and control groups is a serious one in mastery learning research in general, but the inclusion criteria used in the present review have the effect of eliminating the studies in which time differences are extreme. Mastery learning studies in which experimental classes receive considerably more instructional time than control classes are always either very brief, rarely more than a week (e.g., Anderson, 1975a, b; Arlin & Webster, 1984), or they involve individualized or self-paced rather than group-paced instruction (e.g., Jones, 1974; Wentling, 1973). In studies of group-paced instruction conducted over periods of at least four weeks, extra time for corrective instruction rarely amounts to more than 20-25% of original time. It might be argued that additional instructional time of this magnitude might be a practicable means of ensuring all students a reasonable level of achievement, and the costs of such an apporach might not be far out of line with the costs of current compensatory or special education.

Table 3 Here

Table 3 summarizes the characteristics and outcomes of group-based mastery learning studies in which the mastery learning classes received extra time for corrective instruction. All four of the studies in this category took place at the secondary level, grades 7-10. Also, these studies are distinctly shorter (5-6 weeks) than were most of the studies listed in Tables 1 and 2.

The median effect size for immediate posttests from the five comparisons in four studies is +.31, but none of three retention measures found significant differences (median ES = -.03). However, the four studies differ markedly in experimental procedures, so these medians have little meaning.

The importance of the different approaches taken in different studies is clearly illustrated in a study by Long, Okey, & Yeany (1978). In this study, eighth graders were randomly assigned to six classes, all of which studied the same earth science units on the same schedule. Two classes experienced a mastery learning treatment with teacher-directed remediation. After every two class periods, students in this treatment took a diagnostic progress test. The teacher assigned students specific remedial work, and then gave a second progress test. If students still did not achieve at a designated level (the mastery criterion was not described in the article), the teacher tutored them individually. In a second treatment condition, student-directed remediation, students received the same instruction and tests and had the same corrective materials available, but they were asked to use their test results to guide their own learning, rather than having specific activities assigned. These students did not take the second progress test and did not receive tutoring. Students in the third treatment, control, studied the same materials on the same schedule but did not take diagnostic progress tests. Teachers rotated across the three treatments to minimize possible teacher effects.

The results of the Long et al. (1978) study indicated that the teacher-directed remediation (mastery learning) group did achieve considerably more than the control group (ES=+.43), but exceeded the student-directed remedia-

tion group to a much smaller degree (ES=+.19). What this suggests is that simply receiving frequent and immediate feedback on performance may account for a substantial portion of the mastery learning effect. A replication by the same authors (Long, Okey, & Yeany, 1981) failed to meet the inclusion criteria because it had only one class per treatment. However, it is interesting to note that the replication found the same pattern of effects as the earlier Long et al. (1978) study; the teacher-directed remediation treatment had only slightly more positive effects on student achievement than the student-directed remediation treatment, but both exceeded the control group.

The Long et al. (1978) study included a retention test, which indicated that whatever effects existed at the end of the implementation period had disappeared twelve weeks later. Retention is especially important in studies in which corrective instruction is given outside of class time, as any determination of the cost-effectiveness of additional time should take into account the lasting impact of the expenditure.

Another extra-time study which assessed retention outcomes was a dissertation by Fagan (1975), who randomly assigned four teachers and their seventeen seventh-grade classes to mastery learning or control treatments. The mastery learning treatment essentially followed the sequence suggested by Block and Anderson (1975). Students were quizzed at the end of each week, and teachers worked with students who failed to reach an 80% criterion, after which students took a second formative test. The control classes used the same materials and procedures except that they took the formative tests as quizzes. Teachers scored the quizzes, returned them to students, and then went on to the next unit. The teachers followed the same sequence of

activities, but were allowed to proceed at their own pace. As a result, the mastery learning classes took 25 days to complete the five units on "transportation and the environment" while control classes took only 20-21 days.

Unfortunately, there were pretest differences favoring the control classes of approximately 40% of a grade equivalent on Iowa Test of Basic Skills vocabulary scores. Analyses of covariance on the posttests found no experimental-control differences; in fact, adjusted scores slightly favored the control group (ES=-.11). On a four-week retention measure the control group's advantage was slightly greater (ES=-.15). When experimental treatments vary widely in pretests or covariates, statistical adjustments tend to under-adjust (see Reichardt, 1979), so these results must be interpreted with caution. However, even discarding the results for the one control teacher whose classes had high pretest scores, differences still favored the control group on the posttest (ES=-.17) and on the retention test (ES=-.23).

A small study by Hecht (1980) compared mastery learning to control treatments in tenth grade geometry. Students were randomly assigned to treatments, and each of two teachers taught mastery learning as well as control classes. In the mastery learning classes students were given formative tests every two weeks, which were followed by "intensive remedial help for those who needed it" (mastery criteria and corrective activities were not stated). Results on an experimenter-made test favored the mastery learning classes (ES=+.31).

The largest effect sizes by far for any of the studies which met the inclusion criteria were found in a dissertation by Mevarech (1980). In this study, students were randomly assigned to eight Algebra I classes in a 2x2

factorial design. One factor was "algorithmic" vs. "heuristic" instructional strategies. The "algorithmic" treatments emphasized step-by-step solutions of algebraic problems, focusing on lower cognitive skills. The "heuristic" treatments emphasized problem solving strategies such as Polya's (1957) "understanding-planning-carrying out the plan-evaluating" cycle, and focused on higher cognitive skills.

The other factor was mastery learning (feedback-correctives) versus non-mastery. In the mastery learning treatments, students were given formative tests every two weeks. They then had three chances to meet the mastery criterion of 80% correct. Corrective instruction included group instruction by the teacher and/or the researcher herself; peer tutoring; and tutoring outside of class time by teachers and the researcher. The amount of additional time allocated to provide this corrective instruction is not stated, but the author claimed the amount of out-of-class tutoring to be small (Z. Mevarech, personal communication, March 16, 1984). In the non-mastery treatments, students studied the same materials and took the formative tests as quizzes. To hold the different classes to the same schedule, non-mastery classes were given additional problems to work while mastery learning classes were receiving corrective instruction.

The relevant comparisions for the present review involve the mastery learning vs. non-mastery factor. Within the algorithmic classes, the mastery learning classes exceeded non-mastery on both "lower mental process" items (i.e., algorithms) (ES=+.30) and on "higher mental process" items (ES=+.77). Within the heuristic classes, the effects were even greater for both "lower mental process" (ES=+.66) and "higher mental process" items (ES=+.90).

Overall, the evidence for the "extra time" claim is unclear. Effect sizes for the small number of unequal time studies summarized in Table 3 are no more positive than were those reported for other studies using experimenter-made measures (Table 2), in which mastery learning classes did not receive additional time. In fact, both of the unequal time studies which assessed retention found that any effects observed at posttest disappeared as soon as four weeks later. Substantial achievement effects of extra time for corrective instruction appear to depend on provisions of substantial amounts of extra time, well in excess of 20-25%. However, studies in which large amounts of additional time are provided to the mastery learning classes either involved continuous-progress forms of mastery learning or are extremely brief and artificial. What is needed are long-term evaluations of mastery learning models in which corrective instruction is given outside of class time, preferably using standardized measures and/or criterion-referenced measures which register all objectives covered by all classes.

Retention

A total of six comparisons in five studies assessed retention of achievement effects over periods of 4-12 weeks. All six used experimenter-made measures. The median effect size overall is essentially zero, with the largest retention effect (ES = +.49) appearing in the Anderson et al. (1976) study which found no differences on standardized measures.

Discussion

The best evidence from evaluations of practical applications of group-based mastery learning indicates that effects of these methods are moderate at best on experimenter-made achievement measures closely tied to the objectives taught in the mastery learning classes, and are essentially nil on standardized achievement measures. These findings may be interpreted as supporting the "weak claim" that mastery learning can be an effective means of holding teachers and students to a specified set of instructional objectives, but do not support the "strong claim" that mastery learning is more effective than traditional instruction given equal time and fair achievement measures. Further, even this "curricular focus" claim is undermined by uncertainties about the degree to which control teachers were trying to achieve the same objectives as the mastery learning teachers and by a failure to show effects of mastery learning on retention measures.

These conclusions are radically different from those drawn by earlier reviewers and meta-analysts. Not only would a mean effect size across the sixteen studies emphasized in this review come nowhere near the mean of around 1.0 claimed by Bloom (1984a, b), Guskey & Gates (1985), Lysakowski & Walberg (1982), or Walberg (1984), but no single study even approached this level. Only one of the sixteen studies had mean effect sizes in excess of the 0.52 mean estimated by Kulik et al. (1986) for pre-college studies of mastery testing. How can this gross discrepancy be reconciled?

First, these different reviews focus on very different sets of studies. Almost all of the studies cited in this review would have qualified for

inclusion in any of the meta-analyses, but the reverse is not true. For example, of 25 elementary and secondary studies cited by Guskey and Gates (1985), only six qualified for inclusion in the present review. Of 19 such studies cited by Kulik et al. (1986), only four qualified for inclusion in the present review. Only two studies, Lueckemeyer & Chiappetta (1981) and Slavin & Karweit (1984), appeared in all three syntheses. The list of mastery learning studies synthesized by Lysakowski and Walberg (1982) is short and ideosyncratic, hardly overlapping at all with any of the other reviews, and Bloom's (1984) article only discusses a few University of Chicago dissertations.

As noted earlier, the principal reason that studies cited elsewhere were excluded in the present paper is that they did not meet the four-week duration requirement. The rationale for this restriction is that this review focuses on the effects of mastery learning <u>in practice</u>, not in theory. It would be difficult to maintain that a two- or three-week study could produce information more relevant to classroom practice than a semester- or year-long study, partly because artificial arrangements possible in a brief study could not be maintained over a longer period. Actually, even four weeks could be seen as too short a period for external validity. For example, in the study with by far the largest mean effect size in the current review (Mevarech, 1980), the author was involved daily with the mastery learning classes, providing in-class assistance, corrective instruction, and individual tutoring. A few classes might have comparable resources at their disposal for a few weeks, but such an arrangement is unlikely to be feasible with many classes over a longer period. Had the duration requirement been set at only eight weeks, the maximum effect size for all studies in the pre-

sent review would have been +0.26 (excluding the experimenter-made measures in the Anderson et al. (1976) study).

In addition to excluding many studies cited elsewhere, the present review included many studies missed in the meta-analyses. These are primarily dissertations and unpublished papers (mostly AERA papers), which comprise twelve of the sixteen studies emphasized in this review. Including unpublished studies is critical in any literature review, as they are less likely to suffer from "publication bias," the tendency for studies reporting non-significant or negative results not to be submitted to or accepted by journals (see Rosenthal, 1979; Bangert-Drowns, 1986). Other differences in study selection and computation of effect size between the present paper and earlier reviews are important in specific cases. For example, Guskey & Gates (1985) report effect sizes for the Jones, Monsaas, & Katims (1978) study of +.41 for an experimenter-made measure and +.33 for a standardized test, while the present review estimated effect sizes of +.18 and +.09, respectively. The difference is that in the present review pretest differences (in this case favoring the experimental group) were subtracted from the posttest differences. Similarly, Guskey & Gates (1985) report a single effect size of +.58 for the Anderson et al. (1976) study, ignoring the striking difference in effects on standardized as opposed to experimenter-made measures emphasized here.

There are several important theoretical and practical issues raised by the studies of group-based mastery learning reviewed here. These are discussed in the following sections.

Why are achievement effects of group-based mastery learning so modest? The most striking conclusion of the present review is that other than perhaps focusing teachers and students on a narrow set of objectives, group-based mastery learning has modest to non-existent effects on student achievement in studies of at least four weeks' duration. Given the compelling nature of the theory on which mastery learning is based, it is interesting to speculate on reasons for this.

One possible explanation is that the corrective instruction provided in practical applications of mastery learning is simply not enough to remediate the learning deficits of low achievers. In none of the studies emphasized in this review did corrective instruction occupy more than one period per week, or 20% of all instructional time. This may be enough to get students up to criterion on very narrowly defined skills, but not enough to identify and remediate serious deficits, particularly when corrective instruction is given in group settings or by peer tutors (as opposed to adult tutors). Studies of students' pace through individualized materials routinely find that the slowest students require 200-600% more time than the fastest students to complete the same amount of material (Arlin & Webster, 1976; Carroll, 1963; Suppes, 1964), far more than what schools using mastery learning are likely to be able to provide for corrective instruction (Arlin, 1982).

The amount of corrective instruction given in practical applications of group-based mastery learning may be not only too little, but also too late. It may be that one or two weeks is too long to wait to correct students' learning errors; if each day's learning is a prerequisite for the next day's lesson, then perhaps detection and remediation of failures to master indivi-

dual skills needs to be done daily to be effective. Further, in most applications of mastery learning, students may have years of accumulated learning deficits that one day per week of corrective instruction is unlikely to remediate.

Time for corrective instruction in group-based mastery learning is purchased at a cost in terms of slowing instructional pace. If this time does not produce a substantial impact on the achievement of large numbers of students, then a widespread though small negative impact on the learning of the majority will balance a narrow positive impact on the learning of the few students whose learning problems are large enough to need corrective instruction but small enough to be correctable in one class period per week or less.

However, it may be that the feedback-corrective cycle evaluated in the studies reported here is simply insufficient in itself to produce a substantial improvement in student achievement. As Bloom (1980, 1984b) has noted, there are many variables other than feedback-correction that should go into an effective instructional program. Both the process of learning and the process of instruction are so complex that it may be unrealistic to expect large effects on broadly-based achievement measures from any one factor; instructional quality, adaptation to individual needs, motivation, and instructional time may all have to be impacted at the same time to produce such effects (see Slavin, in press).

Is Mastery Learning a Robin Hood Approach to Instruction? Several critics of mastery learning (e.g., Arlin, 1984a; Resnick, 1977) have wondered whether mastery learning simply shifts a constant amount of learning from high to low achievers. The evidence from the present review is not inconsistent with that view; in several studies positive effects were found for low achievers only. In fact, given that overall achievement means are not greatly improved by group-based mastery learning, the reductions in standard deviations routinely seen in studies of these methods and corresponding decreases in correlations between pretests and posttests are simply statistical indicators of a shift in achievement from high to low achievers. However, it is probably more accurate to say that group-based mastery learning trades coverage for mastery. Because rapid coverage is likely to be of greatest benefit to high achievers while high mastery is of greatest benefit to low achievers, resolving the coverage-mastery dilemma as recommended by mastery learning theorists is likely to produce a "Robin Hood" effect as a byproduct.

It is important to note that the coverage vs. mastery dilemma exists in all whole-class, group-paced instruction, and the "Robin Hood" effect may be produced in traditional instruction. For example, Arlin and Westbury (1976) compared individualized instruction to whole-class instruction, and found that the instructional pace set by the teachers using the whole-class approach was equal to that of students in the twenty-third percentile in the individualized classes, supporting Dahllof's (1971) contention that teachers set their instructional pace according to the needs of a "steering group" of students in the tenth to twenty-fifth percentile of the class ability distribution. Assuming that an instructional pace appropriate for students at

the twenty-third percentile is too slow for higher achievers (Barr, 1974; 1975), then whole-class instruction in effect holds back high achievers for the benefit of low achievers. Group-based mastery learning may thus be accentuating a "Robin Hood" tendency already present in the class-paced traditional models to which it has been compared.

The coverage vs. mastery dilemma and the corresponding "Robin Hood" effect are problematic only within the context of group-based mastery learning, and (at least in theory) only when instruction time is held constant. In continuous-progress or individualized forms of mastery learning in which students can move through material more or less at their own rates, the coverage-mastery dilemma is much less of a concern (Arlin & Westbury, 1976). This does not imply that continuous-progress forms of mastery learning are necessarily more effective than group-based forms; individualization solves the instructional pace problem but creates new problems, such as the difficulty of providing adequate direct instruction to students performing at many levels (Slavin, 1984b). However, there are examples of continuous-progress mastery learning programs which have positive effects on standardized achievement tests (see, for example, Cohen, 1977; Cohen & Rodriquez, 1980; Slavin, Madden, & Leavey, 1984; Slavin & Karweit, 1985).

Importance of Frequent, Criterion-Referenced Feedback. Even if we accept the "weak claim" that mastery learning is an effective means of holding teachers and students to a valuable set of instruction objectives, there is still some question of which elements of mastery learning account for its effects on experimenter-made, criterion-referenced measures. There is some evidence that much of this effect may be accounted for by frequent testing

and feedback to students rather than the entire feedback-corrective cycle. Kulik et al. (1986) report that mastery learning studies which failed to control for frequency of testing produced mean effect sizes almost twice those associated with studies in which mastery learning and control classes were tested with equal frequency. Long et al. (1978) compared mastery learning to a condition with the same frequency of testing and found a much smaller effect than in a comparison with a control group that did not receive tests. Looking across other studies, the pattern is complicated by the fact that most which held testing frequency constant also held the control groups to a slower pace than they might otherwise have attained.

Practical Implications. The findings of the present review should not necessarily be interpreted as justifying an abandonment of mastery learning, either as an instructional practice or as a focus of research. Several widely publicized school improvement programs based on mastery learning principles have apparently been successful (e.g., Abrams, 1983; Levine & Stark, 1982; Menahem & Weisman, 1985; Robb, 1985), and many effective non-mastery-learning instructional strategies incorporate certain elements of mastery learning -- in particular, frequent assessment of student learning of well-specified objectives and basing teaching decisions on the results of these assessments. Further, the idea that students' specific learning deficits should be remediated immediately instead of being allowed to accumulate into large and general deficiencies makes a great deal of sense. It may be that more positive results are obtained in continuous-progress forms of mastery learning, in which students work at their own levels and rates. Use of Chapter I, special education, or other resources to provide substantial amounts of instructional time to help lower-achieving students keep up with

their classmates in critical basic skills may also increase student achievement. This review only concerns the achievement effects of the group-based form of mastery learning (Block & Anderson, 1975) most commonly used in elementary and secondary schools.

The "Two Sigma Problem" Revisited. One major implication of the present review is that the "two-sigma" challenge proposed by Bloom (1984) is probably unrealistic, certainly within the context of group-based mastery learning. Bloom's claim that mastery learning can improve achievement by more than one sigma (ES=+1.00) is based on brief, small, artificial studies which almost all provided additional instructional time and (in several cases) the direct assistance of University of Chicago graduate students to the experimental classes. In longer-term and larger studies with experimenter-made measures, effects of group-based mastery learning are much closer to one-quarter sigma, and in studies with standardized measures there is no indication of any positive effect at all. The two-sigma challenge (or one-sigma claim) is misleading out of context and potentially damaging to educational research both within and outside of the mastery learning tradition, as it may lead researchers to belittle true, replicable, and generalizable achievement effects in the more realistic range of 20-50% of an individual-level standard deviation. For example, an educational intervention which produced a reliable gain of .33 each year could, if applied to lower-class schools, wipe out the typical achievement gap between lower- and middle-class children in three years -- no small accomplishment. Yet the claims for huge effects made by Bloom and others could lead researchers who find effect sizes of "only" .33 to question the value of their methods.

Clearly, much more research is needed to explore the issues raised in this review. More studies of practical, long-term applications of mastery learning assessing the effects of these programs on broadly-based, fair measures of achievement are especially needed; ideosyncratic features of the seven studies which used standardized tests preclude any interpretation of those studies as evidence that group-based mastery learning is not effective. In addition, studies carefully examining instructional pace in mastery and non-mastery models are needed to shed light on the coverage-mastery dilemma discussed here. Mastery learning models in which Chapter I or other remedial teachers provide significant amounts of corrective instruction outside of regular class time might be developed and evaluated, as well as models providing daily, brief corrective instruction rather than waiting for learning deficits to accumulate over one or more weeks. The disappointing findings of the studies discussed in this review counsel not a retreat from this area of research but rather a redoubling and redirection of efforts to understand how the compelling theories underlying mastery learning can achieve their potential in practical application.

Mastery learning theory and research has made an important contribution to the study of instructional methods. However, to understand this contribution it is critical to fully understand the conditions under which mastery learning has been studied, the measures that have been used, and other study features which bear on the internal and external validity of the findings. This best-evidence synthesis has attempted to clarify what we have learned from research on mastery learning in the hope that this knowledge will enrich further research and development in this important area.

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Table 1
Equal-Time Studies Using Standardized Measures

Article	Grades	Location	Sample Size	Duration	Design	Treatments	Subjects	Effect Sizes by Group/Measure	Total
Elementary									
Anderson et al., 1976	1-6	Lorain, Ohio	2 sch.	1 yr.	Students in matched ML, control schools matched on ability	ML-Followed Block (1971). Control-Untreated	Math		+.04
Kersh, 1971	5	Suburban Chicago	11 cl.	1 yr.	Teachers/classes randomly assigned to ML, control within each school	ML-Corr. inst. included reteaching, alternative mtls, peer tutoring. Formative tests given every 3-4 wks. Control-Untreated.	Math	middle cl (-) lower cl (+)	0
Gutkin, 1985	1	Inner-city New York	41 cl.	1 yr.	Schools randomly assigned to ML, Control	ML-Formative tests given every month. Control-Untreated.	Reading		+.12
Katims et al., 1977	upper elem	Inner-city Chicago	19 cl.	15 wks.	1 ML, 1 cont class from each of 10 schools. Trts self-selected or principal imposed	ML-specific mtls provided. Control-Untreated.	Reading		+.25
Jones et al., 1979	upper elem	Inner-city Chicago	4 sch.	1 yr.	2 ML schools matched with 2 control schools	ML-specific mtls provided. Cont-Untreated.	Reading		+.09
Secondary									
Slavin & Karweit, 1984	9	Inner-city Philadelphia	25 cl.	26 wks.	Tchrs/classes randomly assigned to ML, cont.	ML-Formative tests given every 2-3 wks. Corr. inst. given by tchrs. Cont-Used same mtls, tests, procedures as ML except for corr. inst. & summative tests	General Math	Hi 0 Lo 0	+.02
Chance, 1980	8	Inner-city New Orleans	6 cl.	5 wks.	Students within each of 3 classes randomly assigned to ML or control	ML-Formative tests given every wk. Mast. crit.= 80-90% Control-Used same mtls, tests, procedures as ML	Reading	Hi 0 Av 0 Lo 0	0

Key:
(+) Non-significant difference favoring ML
0 No difference
(-) Non-significant difference favoring control

Table 2
Equal-Time Studies Using Experimenter-Made Measures

Article	Grades	Location	Sample Size	Duration	Design	Treatments	Subjects	Effect Sizes by Group/Measure	Total	Retention
Elementary										
Anderson et al., 1976	1-6	Lorain, Ohio	2 sch.	1 yr.	see Table 1	see Table 1	Math	Posttest Retention (3 mo.)	+.64	+.49
Kersh, 1971	5	Suburban Chicago	11 cl.	1 yr.	see Table 1	see Table 1	Math		(-)	
Jones et al., 1979	upper elem	Inner-city Chicago	4 sch.	1 yr.	see Table 1	see Table 1	Reading		+.18	
Wyckoff, 1974	6	Suburban Atlanta	4 cl.	9 wks.	Tchrs/classes randomly assigned to ML, control	ML-Mastery criterion 70%. Corr. Inst. was either reteaching to whole class or peer tutoring. Control-Used same mtls, tests, procedures as ML except for corr. inst. and summative tests.	Anthropology	Hi +.03 Lo +.58	+.24	
Fuchs et al., 1985	1	Rural Minnesota	4 cl.	1 yr.	Students randomly assigned to ML, control	ML-students tested on oral rdg passages each wk. Whole rdg grp reviewed until 80% of students got at least 50 wpm correct. Control-students tested every 4-6 wks., all were promoted w/o corr. inst.	Reading	Hi (-) Lo +	+.20	
Elementary and Secondary										
Cabezon, 1984	3,6,8	Chile	46 cl.	1 yr.	Compared classes using ML to classes similar in SES, IQ.	ML-Not clearly specified Control-Untreated	Spanish +.40 Math +.14	Gr3 +.47 Gr6 +.22 Gr8 +.12	+.27	

Table 2 continued
Equal-Time Studies Using Experimenter-Made Measures

Article	Grades	Location	Sample Size	Duration	Design	Treatments	Subjects	Effect Sizes by Group/Measure	Effect Sizes Total	Effect Sizes Retention
Secondary										
Luecke-meyer & Chiappetta, 1981	10	Suburban Houston	12 cl.	6 wks.	Students randomly assigned to ML, control. Pretest differences favored control.	ML-Formative tests given every 2 wks, followed by 2 days of corr. inst. (criterion = 80%) Control-Used same mtls, tests, procedures as ML except for corr. inst. and summative tests	Human Physiology	Posttest Retention (4 wks)	+.39	0
Dunkelberger & Heikkinen, 1984	9	Suburban Delaware	10 cl.	15 wks.	Students randomly assigned to ML, control classes. Tchrs taught ML & Control classes. Posttest given 4 mos. after end of implementation period.	ML-Students had to meet 80% criterion on repeatable tests to go on. Corrective activities available during free time. Control-Used same mtls, procedures, tests. Received detailed feedback and had same corrective mtls available during free time (but no mastery requirement or repeatable tests).	Chem., Physics	Retention (4 mo.)		+.26

Key:
+ Significant difference favoring ML
(+) Non-significant difference favoring ML
0 No difference
(-) Non-significant difference favoring control

Table 3
Unequal-Time Studies Using Experimenter-Made Measures

Article / Secondary	Grades	Location	Sample Size	Duration	Design	Treatments	Extra Time	Subjects	Effect Sizes by Group/Measure	Total	Retention
Long et al., 1978	8	Georgia	6 cl.	5 wks.	Students randomly assigned to 3 trts. Tchrs. rotated across trts.	Tchr-Directed ML-Formative tests given every 2 days. Remedial work given as corr. inst. "If problem persists," indiv. tutoring given by tchr. Student-Directed ML-Same formative tests used, returned to students for self-correction Control-Same inst. but no tests, correctives.	Not Stated	Earth Sci.	Tchr Directed ML vs. Control: Posttest	+.43	
									Tchr Directed ML vs. Control: Retention (12 wks)		+.08
									Tchr Directed ML vs. Student-Directed ML: Posttest	+.19	
									Tchr Directed ML vs. Student-Directed ML: Retention (12 wks)		-.03
Fagan, 1975	7	Dallas, Texas 1 middle class sch., 1 lower class sch.	17 cl.	5 wks.	4 tchrs randomly assigned to ML, control	ML-formative tests given every wk. Tchrs drilled students who failed to achieve 80% criterion, then gave 2nd formative test. Control-Used same mtls. & procedures as ML. Formative tests taken as quizzes.	22%	Transp. & Environ.	Posttest	-.11	
									Retention (4 wks)		-.15

Table 3 continued

Article	Grades	Location	Sample Size	Duration	Design	Treatments	Extra Time	Subjects	Effect Sizes by Group/Measure	Total	Retention
Secondary											
Hecht, 1980	10	Urban, Suburban Midwest	5 cl.	6 wks.	Students randomly assigned to ML, control classes. Two tchrs taught ML & control classes.	ML-Formative tests given every 2 wks., followed by "intensive remedial help" Control-Used same mtls & procedures as ML including both 1st & 2nd formative tests, but no remedial help.	Not Stated	Geometry		+.31	
Mevarech, 1980	9	Chicago, middle class sch.	8 cl.	6 wks.	Students randomly assigned in 2x2 design to "algorithmic strategy" vs. "heuristic strategy" and to ML vs. control.	ML-Formative tests given every 2 wks. Students had 3 chances to obtain 80% criterion. Corr. inst. included grp. inst., peer tutoring, adult tutoring outside of class. Control-Used same mtls & procedures, took formative tests as quizzes. While ML classes received corr. inst., control worked add'l problems.	Not Stated	Alg. I	Algorithmic Strategy +.70 Heuristic Strategy +.83	+.77	